DECAMETER WAVELENGTH RADIO EMISSION OF JUPITER AS AN INDICATION OF HIGH-VELOCITY FLUXES AND SHOCK WAVES IN THE SOLAR WIND

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DECAMETER WAVELENGTH RADIO EMISSION OF JUPITER AS AN INDICATION OF HIGH-VELOCITY FLUXES AND SHOCK WAVES IN THE SOLAR WIND

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In work [1] it was shown that geoeffective fluxes and shock waves, traversing the magnetosphere of Jupiter, cause radio bursts in the decameter wavelength range. In this way, the possibility arises of determining the average velocities of the fluxes and shock waves in the solar wind at distances of 1 to 5.2 astronomic units.

For geoeffective fluxes with small angular dimensions

$$\nu = \frac{s}{\Delta t \pm \Delta t_1}, \qquad (1)$$

where s and ν -- average distances and velocity of plasma between the orbits of Earth and Jupiter; Δt -- time lag of the radio bursts of Jupiter relative to geomagnetic disturbances corresponding to a given active area on the sun; $\Delta t_1 = \phi/\Omega, \phi$ -- angle between the Earth-sun and Jupiter-sun directions, Ω -- angular velocity of the sun's rotation; "minus" sign corresponds to the period before opposition, and "plus" sign corresponds to the period after opposition. For shock waves, as the result of large angular dimensions of the front [2-4], the velocity $\nu_f = s/\Delta t$.

The results of work [1] relate to a period of a high level of solar activity. We are interested in investigation as to whether or not a similar tie exists for minimum solar activity.

Represented on Figure 1 are the index of geomagnetic activity K_p, primary days of geomagnetic disturbances [5], and daily values of the K_p index (ΣK_p), transformed to the magnetosphere of Jupiter with calculation of the speed and mutual location of the planets relative to the sun (opposition of Earth and Jupiter 10 November 1964). The velocity of geoeffective fluxes near the Earth was determined according to ΣK_p in accordance with [6] for shock waves [4]. Let us assume that ν = a constant down to the orbit of Jupiter. During the "movement" of the geomagnetic disturbances toward Jupiter, it is necessary to differentiate the disturbances connected with long-acting (in the limits of half a revolution) fluxes of the solar wind and those which are caused by shock waves. The latter may be isolated using data on intensity of cosmic emissions in which the Forbush decrease [2-4] is observed during the approach of a shock wave.

Also presented on Figure 1 are data on observation of radio emission of Jupiter from the Boulder station on frequencies of 7.6 to 41 MHz [7] and the flux intensity S is expressed in a three point scale. The maximum durations of radio bursts are 200 minutes, and the minimum ones are several minutes.

In that Jupiter's satellite Io controls the appearance of decameter wavelength radio emission [8-10] it is necessary to differentiate the bursts of radio emissions connected with Io from those not depending on it. Radio bursts whose probability of a connection with Io is greater than 0.4 are noted on Figure 1 with lines. Bursts whose probability of being connected with Io is less than 0.2 are noted with cross-hatched rectangles.

Regardless of the fact that the reviewed period is close to the minimum in solar activity (1964), relatively strong geomagnetic disturbances and extended radio bursts on Jupiter corresponding to them were characteristic for the

September-October period, while during the November-December period, geomagnetic disturbance and radioactivity of Jupiter were noticeably weaker.

Bursts in the decameter wavelength range correspond to the largest part of geomagnetic disturbances transformed to Jupiter's magnetosphere, while bursts of points 2 and 3 are practically all connected with geomagnetic disturbances. The exception is the extended radio burst of 23-25 October of .3, which can not be identified with a noticeable increase in K_p. Therefore, solar data for this period was reviewed [11]: on 6 October, active region 63 (25N, 38W) appeared, in which a series of bursts was observed on 6-11 October. In connection with this it is possible to assume that shock waves connected with the bursts on the dial were generated in this region on 10 and 11 October. Shock waves caused weak geomagnetic disturbances on 12 October, and since the Earth was encompassed by only the lateral edge of the waves, Jupiter did not fall into the wave front (angle $\phi = 30°$).

On the basis of data presented in Figure 1, a cross correlation analysis was conducted between the appearance of radio bursts not connected with Io and geomagnetic disturbances transformed toward Jupiter. The results of the analysis are presented in Figure 2. The only peak of the correlation coefficient which exceeds the 15% level of significance (0.25) is equal to 0.66 ± 0.04.

It should be noted that for the 98 day period reviewed, magnetic disturbances were present on 36 of those days of which radio bursts simultaneously appeared on 33. If only the radio bursts of points 2 and 3 are taken into account, the correlation coefficient between the appearance of these radio bursts and geomagnetic disturbances is equal to 0.85 ± 0.06. Therefore, geoeffective fluxes and shock waves traversing the magnetosphere of Jupiter also cause radio bursts in the decameter wavelength range during minimum solar activity.

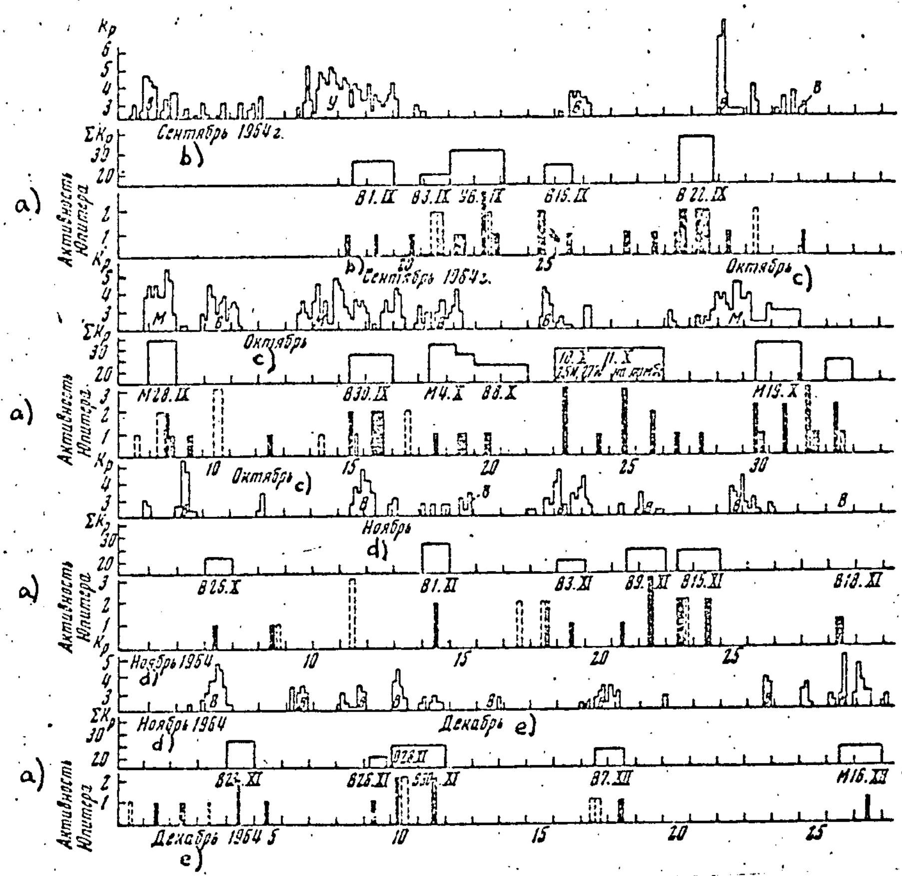

Fig. 1

Key: a) activity of Jupiter b) September 1964 c) October d) November e) December

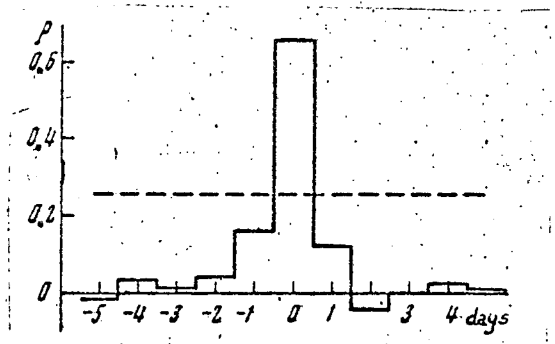

Fig. 2

In that we assumed ν = constant to Jupiter, and the maximum coefficient of correlation corresponds to movement at zero day (Figure 2) it can be said that solar corpuscular fluxes and shock waves are spread close to the orbit of Jupiter with constant velocities.

The connection established allows determination to be made of the average velocities of the fluxes and shock waves at distances of 1 to 5.2 astronomical units according to the lag of Jupiter's radio bursts relative to corresponding geomagnetic disturbances. The results of these computations are presented in Tables 1 and 2. Table 1 shows data on the major days of geomagnetic disturbances in 1964, the daily values of the K_p index, velocities of the solar wind close to the orbit of the earth, determined according to ΣK_p and at a distance of 1 to 5.2 astronomic units according to radio bursts of Jupiter in accordance with (1). Table 2 presents data on the Forbush decrease, the daily index K_p, the amplitudes of the effects in the neutron component (Deep River), the average velocities of the shock waves between the sun and Earth according to [4] and of those between the Earth and Jupiter.

Comparing the velocities obtained by the two methods, it can be said that they agree with each other sufficiently well, although they do have places of exception (19 and 21 October). For comparison, average velocities of the fluxes and shock waves in 1960 computed by the same method are presented in Tables 1 and 2. It can be seen that velocities of geoeffective fluxes from 1960 to 1964 decrease noticeably from $\nu \sim 700$ to $\nu \sim 600$ km/sec. For the shock waves this decrease was not observed. The connection between the radio bursts of Jupiter and the shock waves allows the conclusion to be drawn that they are distributed up to 5 astronomic units with average velocities of $\sim$700-900 km/sec.

Table 1

1) Дата	ΣK_p	$v_{\Sigma K_p}$, 2) км/сек	v_{3-10}, км/сек 2)
1.IX	26	550	550
3.IX	20	500	500
8.IX	31	600	650
30.IX	28	600	600
4.X	32	650	650
19.X	33	650	750
21.X	25	550	700
1.X	27	550	550
5.XI	20	500	550
9.XI	25	550	600
23.XI	28	600	600
26.XI	20	500	500
28.XI	25	550	550
30.XI	25	550	600
7.XII	22	550	600
3) Средние за 1964 г.:		560±40	600±50
4) за 1960 г.:		710±60	710±90

Table 2

1) Дата	ΣK_p	$\delta I/I$, %	$\bar{v}_{C-3}$, 2) км/сек	$\bar{v}_{3-10}$, км/сек 2)
19.IX	24	4	700	750
22.IX	35	6	800	850
28.IX	34	5	700	700
26.X	22	3	700	650
15.XI	24	6	800	850
16.XII	22	4	700	650
3) Средние за 1964 г.:			730±40	740±70
4) за 1960 г.:			720±30	700∓40

Key to tables: 1. date 2. km/sec 3. average for 4. for

IX = September, X = October, etc.

Bibliography

[1] Kovalenko, V.A., *Astron. J.*, 48, No. 3 (1971) 607.

[2] Krymskiy, G.F., *News of the Academy of Sciences, USSR*, 33 (1969) 1858.

[3] Dorman, L.I., I.S. Kaminer, T.V. Kebuladze, *Geomagnetism and Aeronomy*, 9 (1969), 617.

[4] Harang, L., *Planet. Space Sci.*, 16 (1968) 1095.

[5] Afanas'eva, V.I., *Catalog of Geomagnetic Storm Series for the Period 1957-1964*, IZMIRAN, 1968 preprint.

[6] Kovalenko, V.A., V.N. Malyshkin, *Research on Geomagnetism Aeronomy and Physics of the Sun*, 11th ed., Irkutsk (1970) 194.

[7] Warwick, I.W., G.A. Dulk, *IGY Solar Activity Report*, No. 32, Boulder, Colorado (1965).

[8] Big, E.K., *Nature*, 203 (1964) 1088.

[9] Dunkan, R.A., *Planet. Space Sci.*, 14 (1966) 1291.

[10] Wilson, R.G., I.W. Warwick, *Nature*, 220 (1968) 1215.

[11] Bulletin "Solar Data of 1964," No. 11, *Nauka* (1965).

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